SDHCAL simulation status
and how to run it

Guillaume Garillot

- The SDHCAL prototype simulation consists in 2 tools :
  - A Geant4 simulation that simulates propagation and interaction of particles in the SDHCAL
  - A MarlinReco package (SimDigital) that modelises RPC response

- To install :
  - git clone https://github.com/SDHCAL/SDHCALSim
  - cd SDHCALSim
  - mkdir build ; cd build
  - cmake -C $ILCSOFT/ILCSoft.cmake
  - make install

- Run a simple example :
  - modify line 12 the script/example.py and put the correct path
  - launch example.py
  - it will simulate 10 10GeV electrons

- To Create your own script
- Global parameters :
  - physicsList , nEvent , seed , outputFileName

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'
```

- To Create your own script
- Add particle gun :
  - set particleName

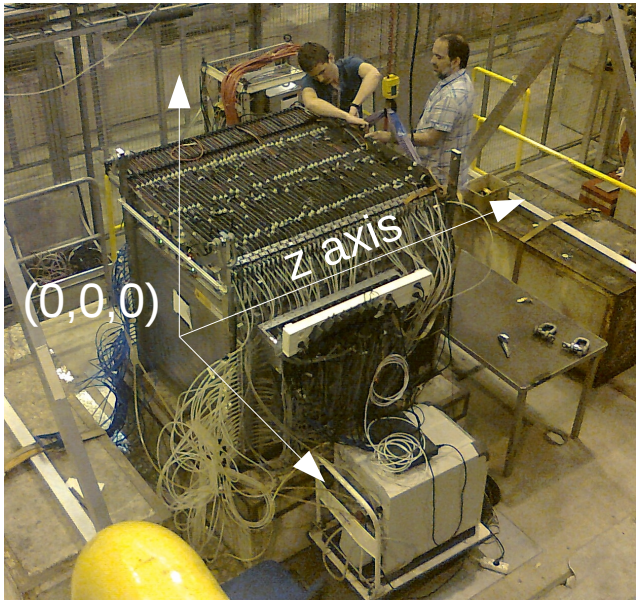
```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
```

- To Create your own script

- Add particle gun :
  - particle gun position options :

  - fixed :
    - fixed position defined by :
      - positionX , positionY , positionZ (in mm)

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

        os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

        params = sim.Params()
        params.physicsList = 'QGSP_BERT'
        params.nEvent = 10
        params.seed = 0
        params.outputFileName = 'outputFile'

        particle = sim.Particle()
        particle.particleName = 'pi-'
        particle.positionOption = 'fixed'
        particle.positionX = 0
        particle.positionY = 0
        particle.positionZ = -20
```



- To Create your own script

- Add particle gun :
  - particle gun position options :

  - uniform :
    - 2D square in the XY plane centered on positionX , positionY with half width uniformDeltaPos

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'uniform'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.uniformDeltaPos = 10
```

- To Create your own script

- Add particle gun :
  - particle gun position options :

  - gaus :
    - 2D gaussian in the XY plane centered on positionX , positionY with sd sigmaPos

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'gaus'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.sigmaPos = 10
```

- To Create your own script

- Add particle gun :
  - particle gun position options :

  - cosmic :
    - launch particles from everywhere with all possible angles
    - mainly used with muons for multiplicity study

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'mu-'
       particle.positionOption = 'cosmic'
```

- To Create your own script

- Add particle gun :
  - particle gun momentum options :
  - (momentum means only direction here, not the relativistic quantity)

  - fixed :
    - launch all the particles along the axis defined by momentumPhi and momentumTheta
    - theta = 0 is aligned with z axis

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'gaus'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.sigmaPos = 10

       particle.momentumOption = 'fixed'
       particle.momentumPhi = 0
       particle.momentumTheta = 0
```

- To Create your own script

- Add particle gun :
  - particle gun momentum options :
  - (momentum means only direction here, not the relativistic quantity)

  - gaus :
    - launch all the particles in a conic distribution centered along the axis defined by momentumPhi and momentumTheta
    - the openness of this conic distribution can be set using the sigmaMomentum parameter

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'gaus'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.sigmaPos = 10

       particle.momentumOption = 'gaus'
       particle.momentumPhi = 0
       particle.momentumTheta = 0
       particle.sigmaMomentum = 5
```

- To Create your own script

- Add particle gun :
  - particle gun momentum options :
  - (momentum means only direction here, not the relativistic quantity)

  - if you used cosmic position option you don't have to care about momentum settings

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'mu-'
       particle.positionOption = 'cosmic'
```

- To Create your own script

- Add particle gun :
  - particle gun energy options :

  - fixed :
    - all the particles from this gun will have the same energy defined by the energy parameter (in GeV)

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'gaus'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.sigmaPos = 10

       particle.momentumOption = 'gaus'
       particle.momentumPhi = 0
       particle.momentumTheta = 0
       particle.sigmaMomentum = 5

       particle.energyDistribution = 'fixed'
       particle.energy = 50
```

- To Create your own script
- Add particle gun :
  - particle gun energy options :
  - uniform :
    - energy of particles uniformely distributed between minEnergy and maxEnergy
    - convenient for MVA training

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

       os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

       params = sim.Params()
       params.physicsList = 'QGSP_BERT'
       params.nEvent = 10
       params.seed = 0
       params.outputFileName = 'outputFile'

       particle = sim.Particle()
       particle.particleName = 'pi-'
       particle.positionOption = 'gaus'
       particle.positionX = 0
       particle.positionY = 0
       particle.positionZ = -20
       particle.sigmaPos = 10

       particle.momentumOption = 'gaus'
       particle.momentumPhi = 0
       particle.momentumTheta = 0
       particle.sigmaMomentum = 5

       particle.energyDistribution = 'uniform'
       particle.minEnergy = 1
       particle.maxEnergy = 120
```

- To Create your own script
- Add the particle gun to the global params
- Then launch the sim using this params
- You can now execute your script

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

	os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

	params = sim.Params()
	params.physicsList = 'QGSP_BERT'
	params.nEvent = 10
	params.seed = 0
	params.outputFileName = 'outputFile'

	particle = sim.Particle()
	particle.particleName = 'pi-'
	particle.positionOption = 'gaus'
	particle.positionX = 0
	particle.positionY = 0
	particle.positionZ = -20
	particle.sigmaPos = 10

	particle.momentumOption = 'gaus'
	particle.momentumPhi = 0
	particle.momentumTheta = 0
	particle.sigmaMomentum = 5

	particle.energyDistribution = 'fixed'
	particle.energy = 50


	params.particleList.append( particle )

	sim.launch( params )
```

- Example if you want to launch two particles for each event :

- You can delay a particle using the time parameter

```
#!/usr/bin/env python

import os
import sys
import SDHCALSim as sim

if __name__ == '__main__' :

	os.environ["SIMEXE"] = '/path/to/SDHCALSim/bin/SDHCALSim'

	params = sim.Params()
	params.physicsList = 'QGSP_BERT'
	params.nEvent = 10
	params.seed = 0
	params.outputFileName = 'outputFile'

	particle1 = sim.Particle()
	particle1.particleName = 'pi-'
	particle1.positionX = -10
	particle1.positionY = -10
	particle1.energy = 50

	particle1.time = 0

	particle2 = sim.Particle()
	particle2.particleName = 'neutron'
	particle2.positionX = 10
	particle2.positionY = 10
	particle2.energy = 20

	particle2.time = 5


	params.particleList.append( particle1 )
	params.particleList.append( particle2 )

	sim.launch( params )
```

- Simulation output :

```
Event 0
Primary particles :

    pdgID : e-
     Time : 0 ns
      Pos : (-12.7654,22.6652,-20)
      Mom : (-0.00918461,0.00170711,0.999956)
   Energy : 10 GeV

Deposited energy : 9.98827 GeV
Leaked energy : 0.000510999 GeV
EM Fraction : 99.9933 %

computing time : 0.18722
average time : 0.18722
-----------------------------------------------------
Event 1
Primary particles :

    pdgID : e-
     Time : 0 ns
      Pos : (-23.9209,47.0567,-20)
      Mom : (0.0202209,-0.112249,0.993474)
   Energy : 10 GeV

Deposited energy : 9.95301 GeV
Leaked energy : 0.00353596 GeV
EM Fraction : 99.8286 %

computing time : 0.1742
average time : 0.18071
-----------------------------------------------------
Event 2
Primary particles :

    pdgID : e-
     Time : 0 ns
      Pos : (30.1543,-57.5725,-20)
      Mom : (-0.00461676,-0.0200372,0.999789)
   Energy : 10 GeV

Deposited energy : 9.99438 GeV
Leaked energy : 0.00561786 GeV
EM Fraction : 100 %

computing time : 0.168006
average time : 0.176475
-----------------------------------------------------
```

- The simulation produces 2 files :
  - A root file which contains debug variables
  - The slcio file which contains the SimCalorimeterHits
  - This slcio file has to be 'digitized' using SimDigital

- SimDigital : MarlinReco processor to simulate RPC response
- Included in ilcsoft since 01-19-05 version

- Steering script example :
  - /gridgroup/ilc/garillot/MarlinReco/script/steer.xml

- launch with :
  - Marlin steer.xml

- Produce a lcio file that has the same format as SDHCAL data
- It also contains a LCRelation collection to link hits with primary particles, to help identify hits from 2 nearby showers

- This example steering file sets up a completely uniform detector (constant efficiencies and multiplicities for all the RPCs)

- To simulate the multiplicities variations you need to apply this changes :

```
...

<!--Induced charge simulation parameters-->
<parameter name="PolyaOption" type="string"> PerAsic </parameter>
<parameter name="PolyaMapFile" type="string"> /gridgroup/ilc/garillot/files/DigitMap/Polya_730677.root </parameter>

...
...

<!--Induced charge dispatching : dispatching mode-->
<!-- Define the charge splitter method. Possible option : Erf , Exact , ExactPerAsic -->
<parameter name="ChargeSplitterOption" type="string"> PerAsic </parameter>
<parameter name="SpreaderMapFile" type="string"> /gridgroup/ilc/garillot/files/DigitMap/Polya_730677.root </parameter>

<!--Step efficiency correction method : should be Uniform or PerAsic-->
<parameter name="EffMapOption" type="string"> PerAsic </parameter>
<!--Value of the constant term for efficiency correction if EffMapOption==Uniform-->
<parameter name="EffMapConstantValue" type="float"> 0.96 </parameter>
<!--File name where prototype efficiency correction is stored if EffMapOption==PerAsic-->
<parameter name="EffMapFile" type="string"> /gridgroup/ilc/garillot/files/DigitMap/Eff_730677.root </parameter>
```

- The non uniform multiplicity is tuned to reproduce the October 2015 Test Beam, thus the agreement is not optimal on other test beams

- Other tools :
  - CaloSoftWare / SDHCALMarlinProcessor (originally coded by Arnaud Steen)
  - https://github.com/ggarillot/CaloSoftWare
  - https://github.com/ggarillot/SDHCALMarlinProcessor
  - (both are needed)